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Effects of Short and Long Study Times on Learning by Maps Versus Navigation

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EFFECTS OF SHORT AND LONG STUDY TIMES ON LEARNING BY MAPS VERSUS NAVIGATION

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ABSTRACT

This experiment compares the spatial knowledge acquired from maps with that acquired from actual navigation of a novel environment. Ninety-six college students, half male and half female, were assigned to one of four experimental conditions: short or long experience with a map or short or long experience in navigation. Subjects were asked to give both route and Euclidean distance estimations for pairs of locations in the learned environment.

Based upon multidimensional scaling analysis, navigation subjects were found to be more accurate than map learners. Longer exposure times led to more accurate estimations. Finally, none of the spatial ability measures taken correlated significantly with performance on the distance estimations.

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INTRODUCTION

Human spatial cognition has been a topic of interest for researchers in psychology for well over 30 years. Relevant literature is piecemeal. There is little continuity among the various studies, and replication of work is even more infrequent. Researchers seem to be poorly informed concerning the studies in their own field, much less from other fields such as geography.

Human spatial cognition, also known as cognitive mapping, has been defined as "the process by which individuals and groups acquire, code, store, recall, and decode information about the relative locations and attributes of the everyday, large-scale, spatial environment," (Moore & Golledge, 1976, p. 5). Researchers are still not in agreement as to the nature of the cognitive mapping process itself, the best way to investigate what is learned, or the best way to analyze the information obtained. It is also not clear whether performance on current spatial ability tests has any relationship to performance on environmental learning tasks. In addition, contrary to much of the previous spatial ability literature (McGee, 1979), few sex differences have been found in environmental learning studies.

Most research has shied away from examining the internal representation or "mental map" since there is still debate over whether such a hypothetical construct as a map in the brain actually exists. Instead, research has focused upon three main variables concerning the gathering of information about the environment. One variable is the mode of presentation of the environmental information. For example, the information can be presented on a map, or through actual experience of the environment. A second variable is the length of time given to learn the environment. The role of this variable is to determine not only if increased exposure leads to increased knowledge, but also whether one mode of presentation leads to faster learning than another. The third variable is the means by which the information learned is examined by the researcher. Two of the most popular of these methods are to have the subjects give estimations of distance between points in that environment, and have the subjects draw sketch maps of what they have learned. This study was designed to examine more fully two of these important variables: mode of presentation, and length of presentation. The study was designed to be similar to the study done by Thorndyke and Hayes-Roth (1982), but employing different specifications of the amount of experience of the subjects.

What Is Cognitive Mapping?

Russell and Ward (1982) address the interaction between man and his environment; the environment sometimes leads to a "direct causal influence upon behavior, " but more often, people are goal-directed, and "devise plans [based] on images of another place." (p. 654) This importance of "image" seems to be an extension of the Boulding (1956) position which states that behavior relies on image rather than on reality. The image of interest, is often called a "cognitive map," although a cognitive map may not be an image in the strictest sense.

Kuipers (1982), for example, says that a cognitive map may not really be an actual map within a person's mind, but it is an often useful and widely used metaphor to represent knowledge of large-scale environments. Kuipers defines a large-scale environment as "one whose structure is revealed by integrating local observations over time, rather than being perceived from one vantage point" (p. 203). Knowledge about a large-scale environment can be obtained by several methods, of which two will be concentrated on here. Knowledge gained from a map has the advantage of displaying relative distances and directions of a large number of locations simultaneously. To acquire this same knowledge by moving through that environment--navigation--is more difficult and more time consuming, since no one glance offers an overall view, and since both directions and relative distances must be incrementally integrated. On the other hand, a great deal more detail is acquired by actually traversing the environment. Thus, the choice between these two methods of learning should not be "Which one is better?" but instead, "Given a set of circumstances, which one is better?" or, from an applied view, "How can I optimize my time and energy when learning an environment?"

Thorndyke (1980) led a 3-year research program designed to examine (1) how learning occurs from maps, (2) how learning occurs from navigation, (3) the extent to which accuracy depends on the type of training, and (4) the effect of "clutter" on maps on subsequent learning. A review of the literature indicates our knowledge of environments comes from many sources including direct navigation, maps, photos and verbal information, and is of three types: (1) landmark or memories of prominent features, (2) procedural or memories of sequences for navigating between landmarks, or the path that must be travelled, on foot to get from one point to another, and (3) survey which fits procedural and landmark knowledge into a map-like configuration with fixed coordinates or the shortest, most direct line between two points. These terms can get confusing because various authors talk about "procedural" knowledge but call it "route" knowledge or "navigation"; or talk about "survey" knowledge but refer to it as "crow-flies" and "Euclidean" knowledge (Russell & Ward, 1982). To keep things simple, I will use the terms "route" and "Euclidean" when refering to the two kinds of knowledge and/or distance estimations.

How Subjects Learn Environments

Most of the studies on cognitive mapping have used two methods for teaching subjects a new environment: map-learning and navigational experience. In general, map learners get a global overview of the environment which is not immediately available to navigators. They can see the routes and features, get a notion of spatial layout, and comprehend Euclidean distances. For example, Thorndyke and Stasz (1980) studied the procedures subjects use to acquire knowledge from maps, looking at good versus poor learners.

Navigators, on the other hand, get their information by first-hand interaction with the environment. The navigator receives impressions of the route travelled, and of landmarks along the way. With increasing experience, the navigator also gets a spatial (Euclidean) understanding of the environment, especially when using several different paths to get to the same location. Foos (1982), for example, chose to study whether recall of time and distance would be affected by the amount of information presented during navigation. Herman, Kail, and Siegel (1979) chose to study another aspect of navigation experience. They looked at students' spatial knowledge after 3 weeks, 3 months, and 6 months on campus to see when most information was acquired. They found knowledge of the environment was very good after only 3 weeks, and increased significantly up to 3 months. They did find males to have significantly more landmark knowledge than females, but there were no other sex differences.

Researchers didn't use map-learning and navigation in the same study for comparison until recently (Thorndyke, 1980; Thorndyke & Hayes-Roth, 1982). Thorndyke (1980) concluded from his study that "navigation experience is optimal for estimating route distances....and map learning is optimal for estimating the shortest distance between two points...." He also found that navigation subjects benefitted from increased experience. Map-learners, on the other hand, did not perform significantly better with increased experience. This difference may be due to the fact that his map-learning subjects "varied in the amount of study time they were given after they had completely memorized the map" (p. 8).

These two methods of environmental learning, from maps and through navigation, are assumed to be represented in memory in different ways. It has been demonstrated (Thorndyke & Hayes-Roth, 1982) that subjects who use maps are faster at estimating Euclidean distances than are navigation subjects who must mentally simulate the routes and compute an estimate. On the other hand, with experience, navigation subjects are superior to map-learners on route estimations, and equivalent in Euclidean estimations (Golledge, Rayner, & Rivizzigno, 1982; Thorndyke & Hayes-Roth, 1982).

How Researchers Assess Subjects' Spatial Knowlege

Distance estimations are one way researchers can try to get at what a subject actually knows about his environment. Many researchers (e.g., Byrne, 1979; Foos, 1982; Canter & Tagg, 1975; Sadalla & Magel, 1980; Thorndyke, 1981b) have used distance estimations to try to determine indirectly how a subject is representing an environment.

Other researchers (e.g., Appleyard, 1969; Beck & Wood, 1976; Schouela, Steinberg, Leveton, & Wapner, 1980) have used a different method to try to assess their subjects' spatial information. Their method was to have the subject draw a sketch map of what he remembers about the environment.

Obviously, distance estimations and sketch maps are different methods of examining spatial knowledge, and probably give different kinds of information. For example, Schouela, et. al. (1980) say that sketch maps provide information about the importance of various locations and provide also a progression of detail with increased environmental experience. This is a valuable tool to examine what is learned first and how learning progresses.

Both sketch maps and distance estimations have their proponents and opponents, however. In his review, Evans (1980) questions the use of sketch maps because they may be seriously confounded with an individual's drawing ability, and because the errors in drawing tend to be cumulative. On the other hand, distance estimations look at only two locations at a time, requiring judgments which are more or less independent of the rest of the locations (Sherman, Croxton, & Giovanatto, 1979). Distance estimations can be altered, such as increasing percieved distances, by including other variables such as time to traverse an environment and number of turns (e.g., Byrne, 1979; Canter &Tagg, 1975; Foos, 1982; Kosslyn, Pick, & Fariello, 1974; Lee, 1970).

There have been some attempts to resolve this dilemma. Sherman et al. (1979) sought to overcome the limitations of sketch maps (drawing ability, and cumulative errors) by using building blocks for mapping. Beck and Wood (1976) sought to preserve mapping, and thus the wealth of information it provides, by developing a "mapping language" which utilizes multiple overlays of paper. Still other researchers have decided that distance estimations are an accurate portrayal of the environment (Sherman et al., 1979), especially when one resolves the question of scale (Cadwallader, 1979). According to Cadwallader (1979), it is difficult to compare the results of previous studies because the threshold distance at which overestimation of distances changes to underestimation varies at a function of the scale you're using.

Evans, Manero, and Butler (1981) have used multidimensional scaling (MDS) as a tool for accurately measuring relative distances in sketch map data. Golledge (1977) also suggests using MDS anyalsis. Null (1981) suggested the use of MDS analysis using subjects' distance estimations as the data. Using MDS would also allow a focus on relative distances as a tool to examine how subjects perceive their environments by negating the effects due to the scale a subject used. This suggested technique provided much of the motivation for the methodology used in this current study.

Other Factors Influencing Cognitive Mapping

What other kinds of factors influence a subject's ability to learn or represent an environment? Sex differences, upon first glance, might seem to be an important factor in cognitive mapping in light of the results of previous studies on spatial tasks (e.g., Maccoby & Jacklin, 1974). However, most cognitive mapping research has found no evidence of sex differences in environmental knowledge. For the most part, the sex differences that were found could be attributed to greater travel and exposure to the environment. For example, when the females had more restricted access to their environment than did their male counterparts, they drew more restricted and less accurate sketch maps than did the males (Hart, 1979). Thus, "evidence from real-scale spatial tasks indicated few sex differences" and "when sex differences have been noted, they can often be explained by differences in the extent of neighborhood exposure" (Evans, 1980, p. 276).

Individual differences in spatial ability is another factor which might influence cognitive mapping. It is not unreasonable to assume there are large individual differences in spatial ability just as there are for most other abilities and aptitudes, and if there are, it is pertinent to see whether they affect cognitive mapping ability. One talked about aspect of spatial ability among laypeople is the sense of direction ("he has a great sense of direction" or "she couldn't find her way out of a paper bag"), and most people, when asked, will readily assess their own ability.

Several researchers have examined the accuracy of this personal assessment. Kozlowski and Bryant (1977) asked their subjects to rate their own sense of direction on a 7-point scale and then gave them several measures of orientation performance. Self-rated sense of direction correlated .49 ($p<.01$) with orientation performance, thus individuals with a good sense of direction were better at pointing to unseen goals. Likewise, from another questionnaire, individuals with a self-assessed good sense of direction, as opposed to those with a poor sense of direction, were better at remembering routes and directions, and they enjoyed reading maps and finding new routes to places, $F=7.09$ (1,30), $p<.05$.

Later, Bryant (1982) correlated sense of direction, spatial visualization (from the Mental Rotations test, Vandenberg, & Kuse, 1978), and personality measures such as flexibility and independence. Although most of the individual correlations were low, all the measures together, when combined in a regression equation, accounted for a significant portion of the variance ($p<.05$, N=85). These findings are potentially important because (1) these measures taken together might form a model for predicting spatial task performance, and (2) personality characteristics might affect spatial ability by determining the type of interaction with the environment, from active involvement to passive responding. Thus, these personality correlates might be applied in a practical sense when needing to teach a new environment, as demonstrated by Wood (1973).

Several researchers have examined individual differences with respect to different kinds of memory to see if that affected mapping ability. Thorndyke and Stasz (1980) found that the ability to learn from a map seemed to rely on good visual memory. Thorndyke and Goldin (1981) identified "four categories of individual difference variables that could plausibly be related to cognitive mapping skills: spatial abilities, visual/verbal processing style, motivation, and experience," (p. v) but found that only spatial ability distinguished good mappers from poor mappers. Similarly, Goldin and Thorndyke (1981) selected subjects on the basis of their spatial ability (high versus low ability), tested both groups, and found no differences in memory ability or experience.

Goldin and Thorndyke (1982) found that "visual-spatial abilities were only weakly related to performance....only 6 of 18 correlations between abilities and task performance reached significance, and none was larger than 0.30," (p. 463). Thus, due to insufficient evidence of a reliable and strong correlation between spatial abilities and cognitive mapping ability, it seems premature to draw any conclusions.

One final factor which might affect a subject's ability to represent an environment is the length of presentation or familiarity of that environment. For example, Herman, et al. (1979) tested college freshmen for spatial knowledge of their campus after 3 weeks, 3 and 6 months, and found their spatial knowledge increased up to 3 months. Further increases in spatial knowledge after 3 months were not significant. Beck and Wood (1976) found that long-term residents of a particular environment make better maps than recent arrivals.

Thorndyke and Hayes-Roth (1982) sought to compare different lengths of presentation for environments that were learned by both maps and by navigation. Their map-learners were of three levels: "One group studied the map until they could redraw the map without error.....a second group studied until they reached this criterion and then spent an additional 30 min studying the map. The third group studied the map beyond criterion for an additional 60 min". (p. 565). Their navigation subjects had worked at Rand Corporation (the environment to be tested) for either 1-2, 6-12, or 12-24 months. (For an examination of the predictions and findings of this study, refer to Figures 1 and 2.) In theory, their idea of a comparison of different levels of familiarity with an environment was a good one, however, in practice, it seems to potentially possess several problems. Evans (1980)

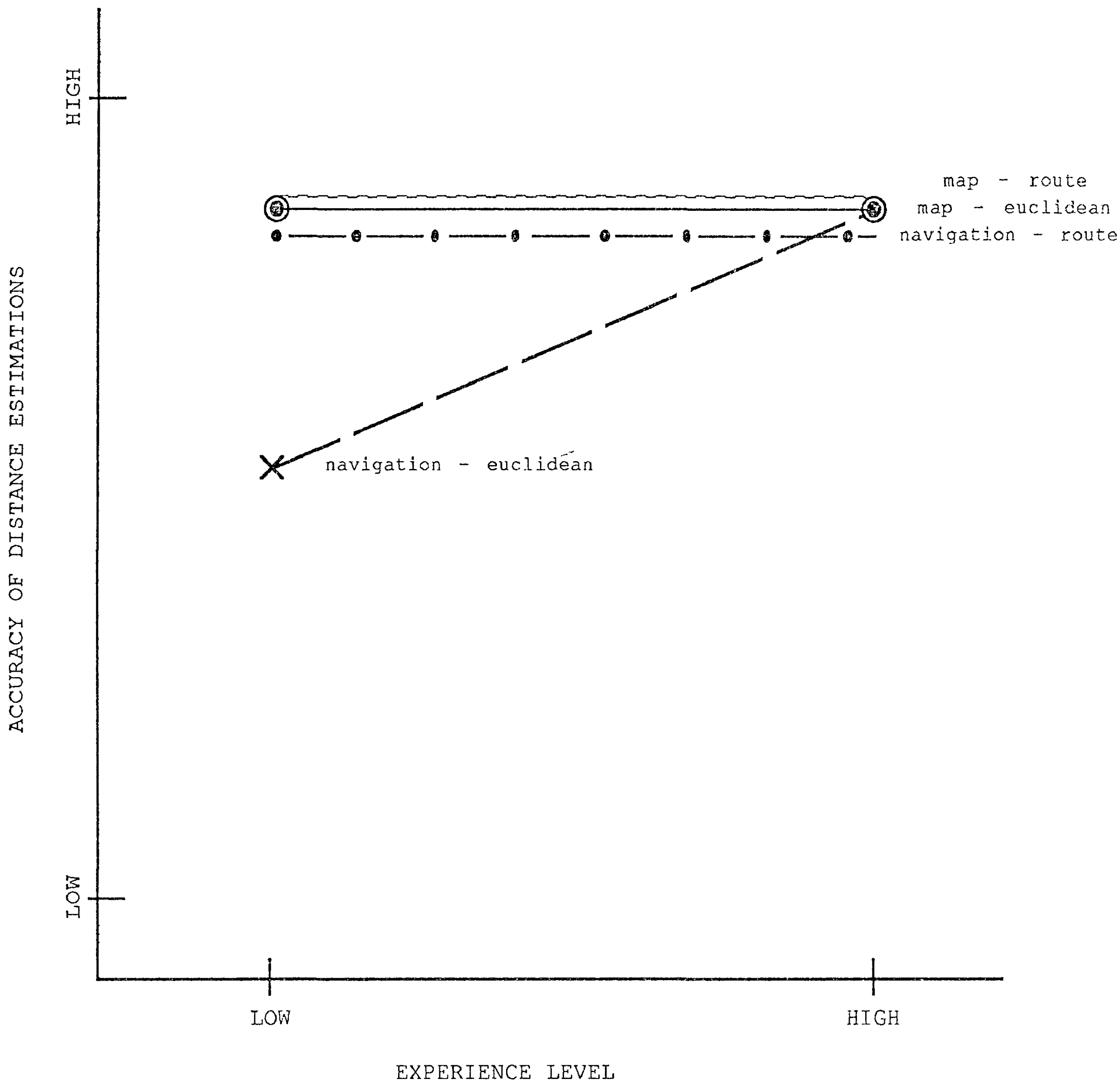


FIGURE 1: PREDICTIONS OF THORNDYKE HAYNES-ROTH (1982)

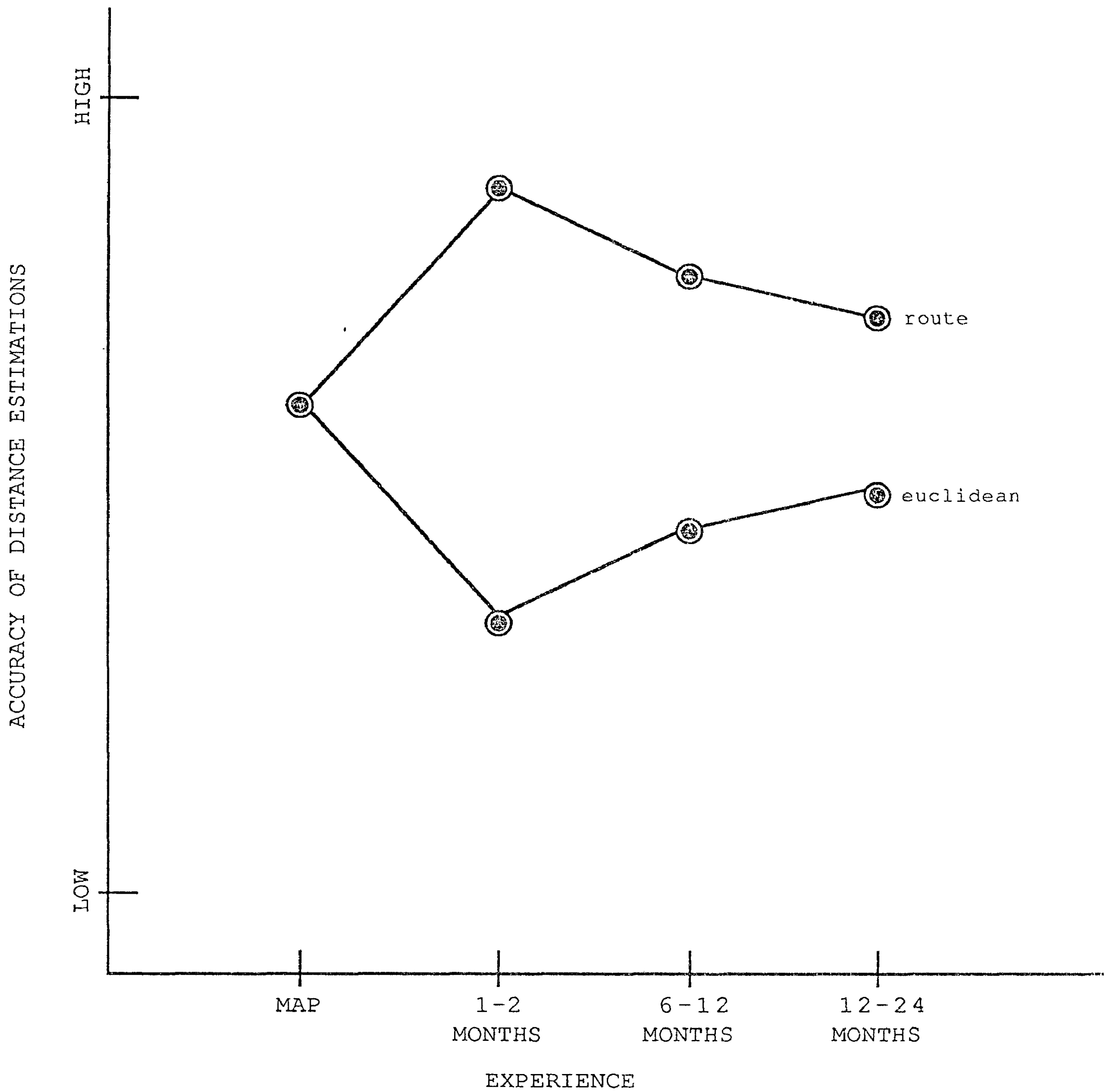


FIGURE 2: RESULTS OF THORNDYKE HAYNES-ROTH (1982)

mentioned that there were two issues in studies of familiarity which warranted futher investigation. First of all, "many researchers have equated familarity with time periods (months, years), ignoring experiential differences in setting exposure across different persons. Second, most of the familarity research has examined large, cross-sectional differences in time."

Thorndyke and Hayes-Roth (1982) are perhaps using groups, in both the mapping and navigation cases, who are not sufficiently different to reflect a true phenomenon. Are the mapping subjects who overlearn for 60 minutes really any more familiar with the environment than those who overlearn for 30 minutes since both groups have demonstrated a criterion of no error? Are all of the navigation subjects getting the same type of experience in the Rand building, or are some more confined to their offices while others dash around the building doing errands? Is the subject who has been an employee for 11 1/2 months really different from one who has been there 12 1/2 months? According to Thorndyke and Hayes-Roth (1982), "because all navigation subjects were familar with tested routes, the accuracy of estimates should improve relatively little with increased experience" (p. 572).

Since it has been found (Herman, et al., 1979) that subjects' knowledge of an environment doesn't increase significantly after 3 months of experience, I wouldn't expect much of a difference between the navigation groups to begin with. Finally, it would be informative to be able to equate the three levels of navigation experience with the three levels of map-learning experience, but that was not really justifiable in their study, although they do attempt to do some comparisons with respect to increased accuracy of distance estimations.

In general, the design used by Thorndyke and Hayes-Roth (1982) seemed to be a potentially useful one since it tried to compare map-learning with navigation-learning, and since it did propose to use several different levels of experience for each. Their method also involved having subjects use both kinds of distance estimations, route and Euclidean, in an attempt to compare differential gains in knowledge depending on type and length of learning. Thus, this research seems a profitable target for replication with a few minor modifications.

First of all, this current research proposed to define more clearly its mapping and navigation subjects with respect to length of exposure. Second, all subjects used were naive, thus ruling out the possible influence of any previous experience with the environment to be learned. Third, there was an attempt to equate more closely the mapping and navigation subjects with respect to actual amount of exposure to the environment. Fourth, since there is still controversy over the absolute accuracy of distance estimations, the distance estimations given here were subjected to a MDS procedure to compare their relative accuracy to the true distances. Fifth, several measures of spatial ability were administered in order to once again try and tap any possible correlations with performance. Finally, this study will check to see if there are any sex differences, such as those found by Herman, et al. (1979).

It was predicted that, overall, the subjects would be fairly accurate in their relative knowledge of the environment. It is also expected that subjects with longer learning times, both map learners and navigation learners, would perform better on both types of distance estimations, Euclidean and route.

METHOD

Subjects

Subjects were 96 introductory psychology students at The College of William and Mary, 48 males and 48 females. They received class credit for participation. All subjects were asked to indicate on the sign-up sheet their choice of a one and a half hour block of time to participate in the experiment. Each subject was picked up at a predetermined location by one of two experimenters and driven to the law school, the experimental environment. Both experimenters were trained to the same instructions (see Appendix C), so that all subjects were exposed to the same experimenter presentation methods.

Five additional subjects, who originally signed up, received credit for this experiment, but were not used as they were familiar with the test environment.

Materials

Tests given to each subject consisted of Form T of the Differential Aptitude Test (DAT) (Bennett, Seashore, & Wesman, 1947) on space relations, and Building Memory (French, Ekstrom, & Price, 1963), a test of visual memory. The DAT is similar to Paper Folding and Mental Rotations (Bryant, 1982).

Additionally, subjects were asked to rate, on a 7-point scale, their own perceived sense of direction, and to answer a few questions about how they, themselves, prefer to learn a new environment. The environmental test site was the first floor of the new William and Mary law school (see Appendices B and C).

Procedure

Half of each of the males and females were trained by navigation through the chosen environment. The remaining half were trained by learning a map of the environment. None of the subjects in either condition had ever seen a map of the environment, nor had any of them ever previously navigated through the chosen environment. Subjects were randomly assigned to condition, were trained and tested individually, and were then informed of the true nature of the study. Experimenters were also randomly assigned to subjects so that both experimenters ran approximately equal numbers of all conditions.

Each of two training conditions included two levels of experience. The navigation subjects had either 5 (low), or 10 (high) minutes of guided navigation through the environment. Five minutes corresponded to navigating once through the building, and ten minutes corresponded to navigating through the building twice. The map learning subjects had studied a map of that environment for either 5 (low), or 10 (high) minutes. There was a 5 minute break between learning and testing for all subjects. Time was filled by a casual conversation between the experimenter and the subject.

Each subject was taken to nine testing locations within the environment. These sites were known as the starting points. In each of the starting points, the subject made judgments for each of the other eight locations, which were known as destinations. These nine starting points and eight destinations were combined for a total of 72 pairs of locations. For each of these pairs, every subject made three judgments: one route distance estimation and two Euclidean distance estimations (a portion of the estimations used by Thorndyke and Hayes-Roth, 1982). Two of these judgments were made at the starting points, and the second Euclidean judgment was made in a neutral location, a study room in the library (see Appendix D for data form).

To begin testing, the experimenter took a subject to one of the starting points. There, the subject was instructed to give two estimations for each stimulus pair. First, the subject was asked to estimate the Euclidean distance, in feet, to a named destination. Second, the subject was asked to estimate the route distance, in feet, to the destination, direct route distance being the length of the actual path taken to reach the destination from the starting point. This procedure of two estimations was repeated for all destination points in each starting point location. The order of starting points was the same for all subjects.

All the subjects in the Thorndyke and Hayes-Roth study (1982) were led through the environment as they performed their estimation tasks, thus all their subjects received some navigation experience. In order not to give the navigation subjects further exposure to the training paths, and also to not give the mapping subjects any navigation experience, all the subjects were led to the starting points by a preset path that was different from the one the navigation subjects received during their training. This path took all the subjects to the locations via a route that went outside the building and on another floor.

Following the completion of these tasks, the subject returned to a library study room to perform one further estimation task. The subject was asked to again estimate the Euclidean distances, in feet, between each of the previously presented pairs. The starting point and destination were named, and the subject had to imagine the rest.

All subjects were then given the DAT, Building Memory, and finally, asked questions concerning individual preference and perceived sense of direction (see Appendix C). These results were later used as a covariate with the dependent measure of performance on the distance estimations, and were correlated with performance.

Since there were true, measurable distances and fixed coordinates for comparison with the estimations given by each subject, (see Appendix E), goodness of fit between the true distances and subjects' estimated distances could be measured by means of multidimensional scaling (MDS).

RESULTS

The distance estimations, for each subject, were put into matrices (see Appendix G), one each for the Euclidean distances, route distances, and second Euclidean distances. ALSCAL (alternate least squares scaling, Takana, Young, & deLeeuw, 1977) was used to obtain a map-like configuration for each of the matrices. ALSCAL, like other MDS techniques, goes from a distance matrix to a geometric representation. If, for example, we had real distances such as the key on a road map, then those distances would transform into a perfect representation with no error or "stress." In doing distance estimations, subjects make errors, thus their geometric representations are not perfect (i. e. the distance from A to B is not always equal to the distance from B to A) and have stress. Another reason for using ALSCAL is because this model allows the use of any of the four measurement levels of data. Since subjects seem, as mentioned above, to use numbers in a manner that is not interval, the ordinal level was used. The true, actual distances (as in a map), both route and Euclidean, were also given a geometric configuration. Since these distances are "true", their geometric configuration corresponds to the actual map or floor plan. Each subject's ALSCAL solution/configuration was rotated with the "true solution" using MOTION, a technique which tries to fit the configurations together in the best possible fit, or that of least residual error (Schonemann & Carroll, 1970).

Both the ALSCAL stress and the MOTION normalized symmetric error were subjected to a 3-way ANOVA to examine the differences between long and short learning times, between map and navigation experience, and between males and females. An ANOVA performed on the ALSCAL stresses from the Euclidean solutions showed only the length of learning to be significant, $\underline{F} = 7.348$ (1, 88), $\underline{p} < .008$. The subjects who had a longer learning time had a lower average stress (.05) than the subjects with a short learning time (.07). Thus, the subjects who had longer learning times gave more consistent Euclidean distance estimations than subjects with shorter learning times.

An ANOVA on the ALSCAL stresses from the route solutions showed only sex to be significant, and only slightly so, $\underline{F} = 4.043$ (1, 88), $\underline{p} < .047$, with males having a lower stress (.06) than females (.08), thus males were slightly more consistent than females on the route distance estimations.

An ANOVA on the ALSCAL stresses from the second Euclidean estimations done from memory found both length of learning, $\underline{F} = 6.677$ (1, 88), $\underline{p} < .011$, and type of learning, $\underline{F} = 10.356$ (1, 88), $\underline{p} < .020$, to be significant. The navigation subjects had lower stresses (.04) than the map subjects (.06), and the subjects with long learning times had lower stresses (.04) than those with short learning times (.06). Thus, for the second Euclidean distance estimation, the navigation subjects were more consistent, within subjects, than the map-learners, and those subjects who had longer learning times were more consistent than subjects with shorter learning times. For the most part, the ALSCAL stresses were low, showing that the distance estimations of each subject were fairly consistent. However, these data say nothing about the accuracy or correctness of the estimations when compared to the actual, real distances.

In order to examine the accuracy of the subjects' estimations, each subject's distance estimations were fitted to the true distances with MOTION. The goodness of fit was given by a measure of normalized symmetric error; the lower the error, the better the fit. When ANOVAs are performed on the normalized symmetric errors obtained from MOTION, a consistent pattern emerges. The ANOVAs on the MOTION Euclidean (E1 and E2) and the MOTION route (RT) normalized symmetric error showed similar results. In each (E1, RT, and E2 respectively) there was a main effect for length of learning, $F = 9.404$ (1, 88), $p < .003$; $F = 8.302$ (1, 88), $p < .005$; and $F = 7.483$ (1, 88), $p < .008$. As can be seen from Table 1 and Figure 3, the subjects who received longer learning times had lower normalized symmetric error, and thus were more accurate in their distance estimations.

TABLE 1

MEAN NORMALIZED SYMMETRIC ERROR FROM MOTION SOLUTIONS BY PRESENTATION TIME

Analysis	Long Presentation	Short Presentation
E1	.20	.29
RT	.18	.26
E2	.14	.23

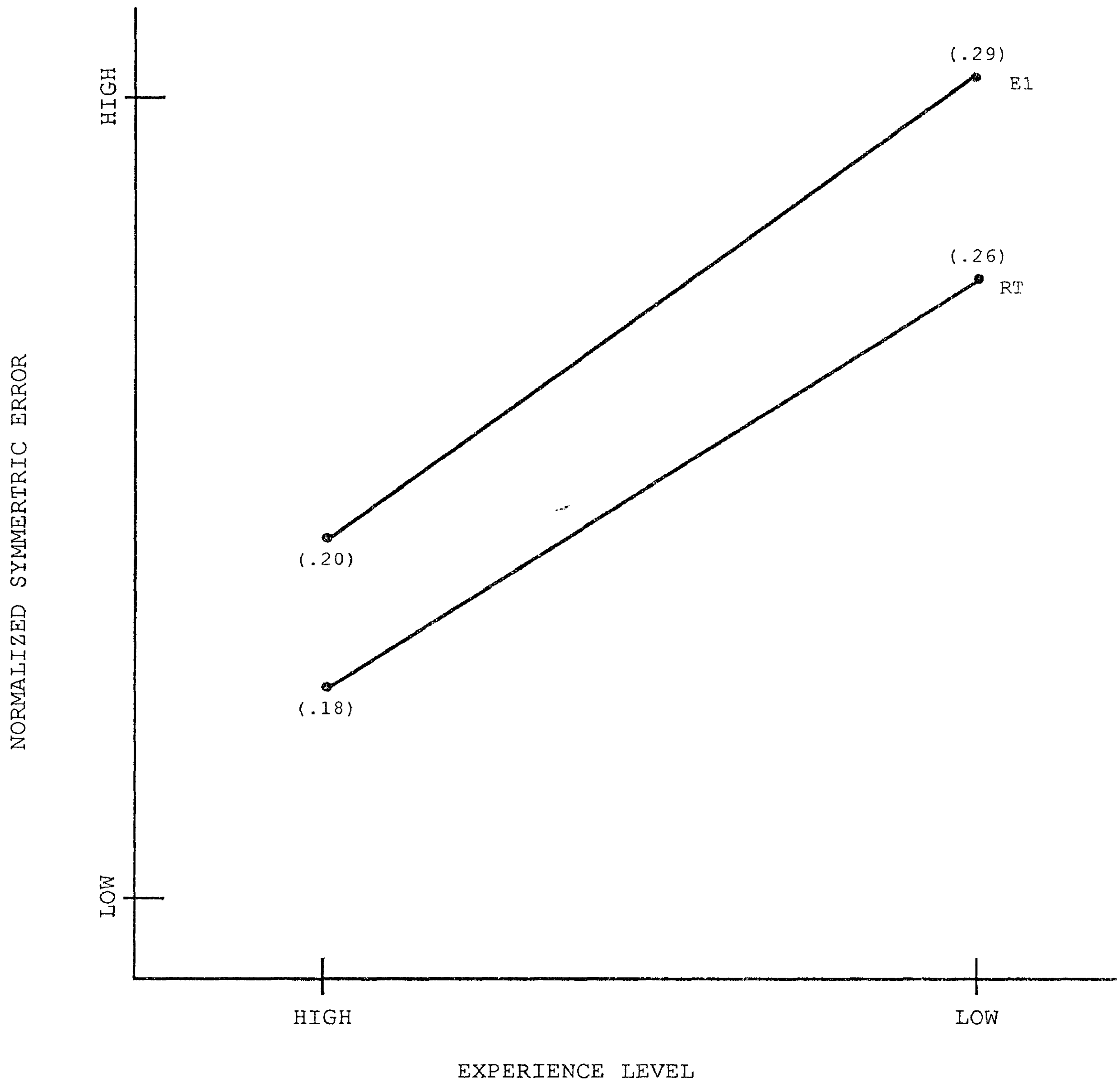


FIGURE 3: RESULTS OF EXPERIENCE LEVEL ON EUCLIDEAN AND ROUTE ESTIMATION

In addition, there was a main effect for the type of learning, for E1, RT, and E2 respectively, $F = 5.781$ (1, 88), $p < .018$; $F = 6.231$ (1, 88), $p < .014$; $F = 9.374$ (1, 88), $p < .003$. As can be seen in Table 2 and Figure 4, the subjects who received navigation experience were more accurate than those subjects who received map experience, for all distance estimations. There were no sex differences and no interactions.

When the results of E1, RT, and E2 were compared in a repeated measures ANOVA, it was shown that the stresses of the E2 were lower than those of RT, which in turn were lower than those of E1. As can be seen from the means in Table 3, it seems that subjects do better on their second chance at distance estimations either from practice or time to firm up whatever representations they have.

The results of E1, RT, and E2 were also subjected to several 3-way ANOVAs with a covariate. When the stresses were covaried with the scores on Building Memory (BM), the Differential Aptitudes Test (DAT), or the self-rated sense of direction, the results were basically the same as those without the covariates, as can be seen in Table 4. None of the covariates were significant. Likewise, a regression equation using DAT, BM, and sense of direction was not significant, thus it is not possible from this data to predict E1, RT, or E2 (performance) from these ability measures.

TABLE 2

MEAN NORMALIZED SYMMETRIC ERROR FROM MOTION SOLUTIONS BY METHOD OF LEARNING

Analysis	Navigation	Map
E1	.21	.28
RT	.18	.26
E2	.14	.23

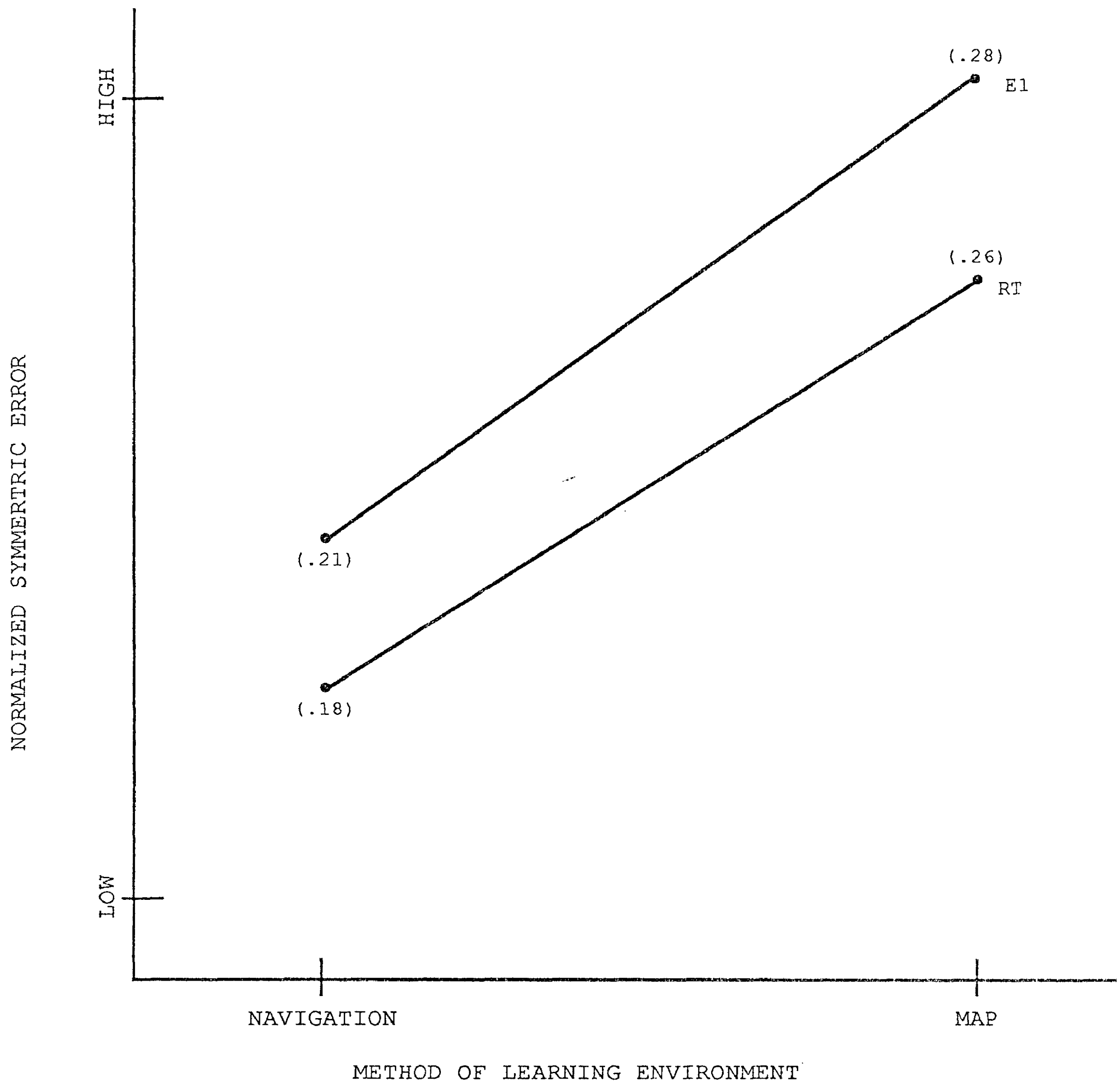


FIGURE 4: RESULTS OF METHOD OF LEARNING ON EUCLIDEAN AND ROUTE ESTIMATIONS

TABLE 3

MEANS AND STANDARD DEVIATIONS OF NORMALIZED SYMMETRIC ERROR FROM MOTION SOLUTIONS

Analysis	Mean	Standard Deviation
E1	0.243	0.122
RT	0.220	0.124
E2	0.186	0.092

TABLE 4

SIGNIFICANT F-RATIOS FOR ANOVAS WITH COVARIATES

Analysis	With DAT	With BM	With Sense of Direction
E1	type F = 6.287 length F = 9.891	type F = 5.457 length F = 9.199	type F = 4.921 length F = 9.147
RT	type F = 7.630 length F = 9.557	type F = 6.270 length F = 8.230	type F = 6.304 length F = 8.334
E2	type F = 10.455 length F = 8.346	type F = 8.464 length F = 7.370	type F = 9.412 length F = 7.519

All above $\underline{F}$'s are significant, $\underline{p} < .05$

Upon looking at the correlations, this finding becomes apparent: DAT correlates with sense of direction, $r = .2195$, $p < .016$; BM correlates with sense of direction, $r = .2296$, $p < .013$; and DAT correlates with BM, $r = .3866$, $p < .0000$. However, none of the three correlate with E1, RT, or E2. Table 5 shows the correlations of the ability measures with the distance estimations.

One of the questions asked of the subjects, tried to examine the subject's preference for a map versus navigation experience when presented with new environments of various sizes. The data for these preferences can be seen in Table 6.

TABLE 5

CORRELATIONS OF DISTANCE ESTIMATION AND ABILITY MEASURES

	DAT	BM	S of D	CF1	RT
DAT	1.000				
	p = 0.000				
BM	0.3866	1.000			
	p = 0.000*	p = 0.000			
S of D	0.2195	0.2296	1.000		
	p = 0.016*	p = 0.013*	p = 0.000		
CF1	-0.0506	-0.0432	-0.0982	1.000	
	p = 0.312	p = 0.339	p = 0.171	p = 0.000	
RT	-0.0010	-0.0114	-0.0259	0.7402	1.000
	p = 0.496	p = 0.456	p = 0.401	p = 0.000*	p = 0.000
CF2	-0.0299	-0.0744	-0.0160	0.6150	0.6424
	p = 0.386	p = 0.237	p = 0.438	p = 0.000*	p = 0.000*

* indicates significance at p < .05

TABLE 6

SUBJECTS' SELECTIONS OF HOW THEY WOULD PREFER TO LEARN A NEW ENVIRONMENT

Environment	Preferred method	
Building	42% map	58% navigation
City	80% map	20% navigation
Receiving directions	65% map	35% verbally

DISCUSSION

On the whole, the results of this study do not agree with those found by Thorndyke and Hayes-Roth (1982). That they do not agree is probably due to a more controlled amount of learning experience for the subjects used in this study. Thorndyke and Hayes-Roth predicted that their map-learners would do equally well on the Euclidean and route distance estimations, and that neither would increase significantly with time. Their results supported their predictions, but the only difference in their different levels of map-learning experience was an additional 30 or 60 minutes of study time beyond a criterion of redrawing the map without error. In contrast, the map-learning subjects from this study got better with increased experience. Although they performed better on route estimations than they did on Euclidean estimations, both types of estimations improved with increased experience.

Thorndyke and Hayes-Roth predicted that their navigation subjects would be better at route estimations than at Euclidean estimations. With increased experience, they predicted that their route estimations would not improve, but that their Euclidean estimations "should increase across experience groups and ultimately approximate the accuracy attained by map-learning subjects," (p. 572), as can be seen in Figure 1. Again, their predictions were supported: the navigation subjects were better at route estimations than at Euclidean estimations; the route estimations were consistent over experience level; the Euclidean estimations improved over experience level. They found all their navigation subjects to be more accurate than map-learners on route estimations, as can be seen in Figure 2.

In contrast, in this study, the navigation subjects were better than the map-learning subjects for both the Euclidean and the route distance estimation, however, both the navigation subjects as well as the map-learners got better with increased experience. Both the map-learners and the navigation subjects were more accurate in their route estimations than in their Euclidean estimations, as can be seen in Figures 3 and 4.

Although Bryant (1982) found that several spatial ability measures, taken together, might provide a model for predicting performance on mapping tasks, the results of this current study could not support his results. However, different tests were used in this study, and perhaps they are not as good at predicting as the ones used by Bryant (1982). Beck and Wood (1976) suggest some personality correlates which appear to predict map performance. Self-related "exploratoriness" and whether the subject uses mass transit or walks seem to relate to map performance. Perhaps future research could follow up on these findings when testing both map and navigation performance.

The questions asked of the subjects at the conclusion of the study tried to investigate what kinds of things might be going on in the minds of the subjects and the ways they preferred to learn about new environments. Although the responses were not analyzed at this time, they did seem to suggest some trends in preferences and also some possibilities for future research in this area. The majority of the subjects expressed a preference of navigation to learn a smaller building-sized environment, but wanted a map when confronted with a new city-sized environment, as shown in Table 6.

As a whole, the subjects' distance estimations were accurate in a relative sense, as illustrated by the small stresses in the MDS solutions, however when asked how they felt about estimating the distances in feet, most felt quite uncomfortable and expressed great doubts as to their accuracy. When they were asked how accurate they were relatively speaking, they expressed more confidence in their estimations. This does support past research (e. g. Cadwallader, 1979) when it questions the accuracy of distance estimations based on an absolute scale, and also lends support to the use of MDS as a method of using the subject's knowledge of relative positions. Overestimations in distance judging, such as those found by Byrne (1979) and Canter and Tagg (1975) can be adjusted for by the use of MDS as it can evaluate relative spatial knowledge.

The close fit between the MDS spatial representations of the subjects' data and the true representations that was demonstrated by the subjects in this experiment is not unexpected, but instead compares with results found by Baum and Jonides (1979): "In fact, various experiments have demonstrated that subjects are remarkably consistent in judging distances,...estimates of distances between landmarks...correlated .95 with actual distances" (p. 462). Not only did the MDS solutions generated from the distance estimates more closely approximate the solutions obtained from the true environment with increased exposure, but the fit for the solutions generated from their Euclidean distance estimations was better when they gave them the second time versus the first time they were given. There are two possible explanations for this. First, the subjects had had time to get accustomed to the distance estimation task, and may have even remembered some of the earlier estimates. A second possibility is that the subjects had been through all the locations in the environment an additional time, although in a novel manner. The map subjects, by making estimations from the real locations, did get some experience with the real environment. This additional exposure could have provided extra familiarity with the environment. Evans, Marrero, and Butler (1981) believe that "individuals initially comprehend the relative positions of items in space, but fine tune the exact location of items in space with increased experience" (p. 101).

An area that bears further investigation is the relationship between a subject's preferred style of learning an environment and his performance when asked to learn it either with or against his preferences. It would be useful to learn if there were any differences in performance, and if so, if either of the preferred modes were more readily switched.

Sadalla and Staplin (1980) have said that "current research on large-scale distance cognition examines distance estimates made in the absence of direct sensory referents, usually subsequent to some active experience with the environment" (p. 184). This piece of research was an attempt to provide, during testing, both immediacy and cues from the actual environment. Previous research has varied in its time between environmental learning and testing, generally due to a lack of experimental control. For example, Baum and Jonides (1979), Schouela, et al., (1980), and Herman, et al. (1979) used subjects who were already somewhat to moderately familiar with the environments. Thorndyke and Stasz (1980) used immediate recall following a map-learning task. Foos (1982) didn't report interstudy-test times for his subjects who had just walked through an environment. Thorndyke and Hayes-Roth (1982) also didn't report length of time between study and test for their map-learning subjects, but their navigation subjects were already familiar with the environment. Thus, it may be that a 5 minute break between study and test could have caused the results obtained here, however, this type of situation would seem to be likely in the real-world. Imagine, for example, someone who asks for and receives directions, and a couple of minutes later, needs to act on that information.

In conclusion, it is interesting to note that all the subjects demonstrated fairly accurate knowledge of this semi-complex, small-scale environment that was learned in a very short time. These subjects only spent 5 or 10 minutes in study rather than the days, months, or years of previous studies. This in itself could be useful to situations when a subject must learn the layout of a particular environment very rapidly, such as in the military. Gross information, such as the general configuration of locations was learned quickly by both navigation and map-learning subjects.

APPENDIX A

CONSENT FORM FOR SUBJECTS

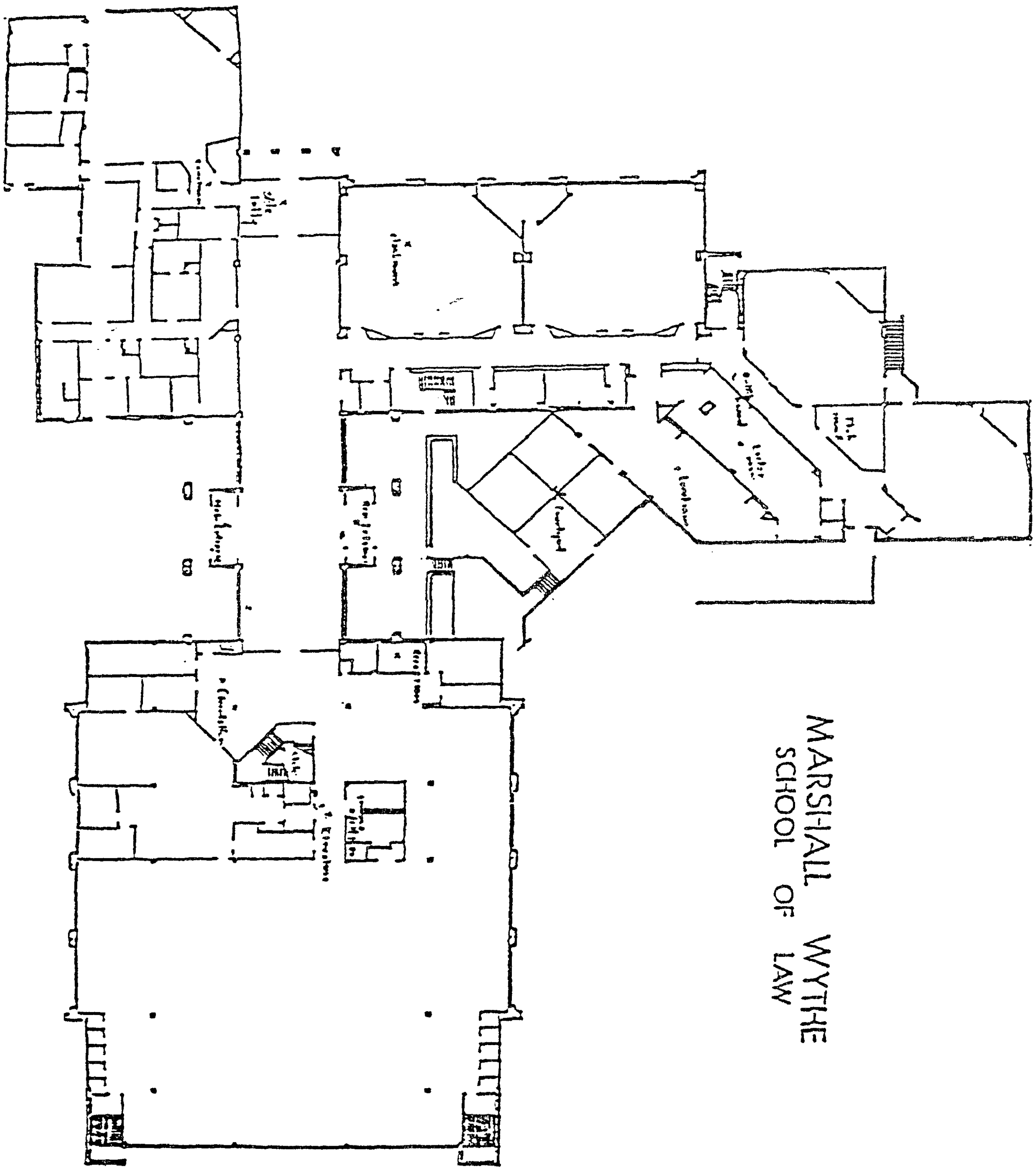
College of William and Mary
Psychology Department Consent Form

The general nature of this experiment on environmental learning conducted by Thyra Rauch has been explained to me. I understand that I will be asked to travel to a location in Williamsburg, learn and environment, answer a few questions about that environment, and take a couple of ability/preference tests. I further understand that my responses will be confidential and that my name will not be associated with any results of this study. I know I may refuse to answer any question and that I may discontinue participation at any time. I also understand that any grade, payment, or credit for participation will not be affected by my responses or by my exercising any of my rights. I am aware that I may report dissatisfaction with any aspect of this experiment to the Psychology Department's Research Ethics Committee. My signature below signifies my voluntary participation in this experiment.

________________ ______________________________
Date Signature

APPENDIX B

MAP OF THE ENVIRONMENT



APPENDIX C

Introduction

Hello. My name is __________, and I'll be conducting an experiment on environmental learning. Have you ever been in the law school? (If so, thank, give credit, explain the study, and dismiss.) Okay, there are several things I'd like you to do. You'll be asked to learn an environment, to answer a few questions about that environment, and to do a few short ability/preference tasks. The entire experiment should take about an hour. This is a fairly simple experiment; most of the tasks are those you'd encounter in everyday living, but if at any time you feel you can no longer continue participation, let me know, and the session will be terminated. Do you have any questions before we begin? Would you please read and sign the consent form. This consent form protects your rights as a subject. It states that all responses you provide today will be kept confidential; that is, your results will in no way be associated with your name. Okay, let's begin.

Instructions to map-learners only

Here is a map of the first floor of the law school. I would like you to study it carefully for X minutes. Notice that most of the important locations have been labeled, and there is a scale of how many inches equal how many feet. (x minutes pass.) Okay, please turn the map over and hand it to me. (Subjects will study map in the original meeting room on campus before they leave.)

Instructions to navigation learners only

We're going to go on a tour of the law school. I would like for you to carefully observe your environment as you walk through. I will point out most of the important locations. We need to keep the talking to a minimum so we don't disturb the other students who are trying to study, okay?

5-minute break instructions between learning and testing

Conversation such as: Where are you from? (Tell where I'm from and, where I went to school, or what I do here in town.) Ask if they have gone to any other college besides William and Mary. (Tell them that my college town was much like this one and has a restored area too, but smaller, or ask them how they like William and Mary). Ask if they've been through Colonial Williamsburg yet. If there is still time, ask what their favorite place in Williamsburg is.

Testing, (standing in the corridor of the library)

Would you please tell me how far, in feet, you are standing from that X (some premeasured object)? We are now going to go to each location in turn and do more judgments just like the one you did. You might experience some frustration in doing these estimations. This is normal. We are taking judgments from people with different amounts of exposure to an environment to see how well they know it after brief amounts of exposure. All that we ask is that you try to do the best job you possibly can, okay? Let's go.

We are now standing in ________(location). I want you to think of a Euclidean distance as the straight line, through walls and obstacles, from one point to another. Would you please tell me, to the best of your ability, the distance in feet, as the crow flies, to the center of__________________ (destination). Now, if you had to walk from here to __________(destination), how far in actual feet would you have to travel? (Repeat for the other 7 destinations). We're now going to the next testing location; please follow me.

(Use this form for each of the 9 starting points.)

Instructions for the abilities tests

(All instructions for the DAT and Building Memory were read verbatum from the instructions provided in the test booklet. The examples were explained to the subjects, and the subjects were asked if they understood the directions.

Questions after testing

(Written:)

1. How would you rate your own sense of direction, on a 7-point scale. Assume 1 corresponds to very poor and 7 to very good.
2. If you are learning a new environment, such as a building, is it more helpful for you to look at a map, or just wander around the building?

(Oral:)

3. How about a new city? Does the same hold true, or do you use another method?

4. If someone is giving you directions, can you more easily follow them if they are presented verbally, or by a map?
5. Were you in David Uttal's study on campus learning (lived in Yates and Dupont, to see if they have been exposed to this type of task before.)
6. On a scale from 0 to 7 how accurate do you feel your distance estimations were, with 0 being not at all accurate and 7 being very accurate.

   How accurate, again on a 0 to 7 scale, do you feel your judgments were as far as overall relationship. In other words, accuracy aside, how consistent do you feel you were from time to time?
8. Was it easy for you to do estimations in feet? Was the task hard?
9. As you went throught the experiment, do you think your estimations got better, worse, or stayed about the same?
10. Did you have any idea what I was looking for in this study?
11. Which were harder for you, the route estimation or the Euclidean estimations? Why?
12. Which were harder for you, the first Euclidean estimations in the actual locations, or the second ones in the study hall? Why?
13. Did you find this task frustrating?

14. Did you have some sort of a map or image of the environment in your head of what the environment looked like?
15. Did you use this mental map when you were trying to estimate distances?
16. On a scale of 0 to 7 with 7 being the most accurate, how would you rate the accuracy of your own mental map?

Debriefing

What you have just done is to give me Euclidean and actual route distances between several sets of locations. You have been exposed to the environment, the law school, by ________(map or navigation). Half of the other subjects learned this environment by ____________(map or navigation). I will compare these two methods of learning an environment and see if there are any differences in the distance judgments you and the other subjects gave. In addition, I want to see if there is any relationship between the judgments given and the ability/preference measures. Is there anything else you would like to know about this experiment at this time? If you'd like to receive a copy of the results, sign this paper, and I'll mail them to your campus P. O. box when I finish my data analysis. It is important to the success of my study that none of my other subjects know that I am using the law school as the environment they are to learn so that they are as unfamilar with it as you were. Would you please not mention this study to anyone until I have finished running subjects? This is really important. Thank you very much for participating.

APPENDIX D

SAMPLE DATA FORM FOR DISTANCE ESTIMATIONS

Testing location	Destination	Euclidean	Route	Study room
Courtroom	Bulletin board			
	Locker room			
	Lunch room			
	Courtyard			
	Main entrance			
	Circulation			
	Xerox machine			
	Elevators			
Bulletin board	Courtroom			
	Locker room			
	Lunch room			
	Courtyard			
	Main entrance			
	Circulation			
	Xerox machine			
	Elevators			
Locker room	Courtroom			
	Bulletin board			
	Lunch room			
	Courtyard			
	Main entrance			
	Circulation			
	Xerox machine			
	Elevators			
Lunch room	Courtroom			
	Bulletin board			
	Locker room			
	Courtyard			
	Main entrance			
	Circulation			
	Xerox machine			
	Elevators			

Testing locations	Destinations	Euclidean	Route	Study room
Courtyard	Courtroom			
	Bulletin board			
	Locker room			
	Lunchroom			
	Main entrance			
	Circulation			
	Xerox machine			
	Elevators			
Main entrance	Courtroom			
	Bulletin board			
	Locker room			
	Lunchroom			
	Courtyard			
	Circulation			
	Xerox machine			
	Elevators			
Circulation	Courtroom			
	Bulletin board			
	Locker room			
	Lunchroom			
	Courtyard			
	Main entrance			
	Xerox machine			
	Elevators			
Xerox machine	Courtroom			
	Bulletin board			
	Locker room			
	Lunchroom			
	Courtyard			
	Main entrance			
	Circulation			
	Elevators			

Testing location:	Destination:	Euclidean:	Route:	Study room:
Elevators	Courtroom			
	Bulletin board			
	Locker room			
	Lunchroom			
	Courtyard			
	Main entrance			
	Circulation			
	Xerox machines			

APPENDIX E

SAMPLE MATRICES OF ESTIMATIONS OF ONE SUBJECT

	Court-room	Bulle-tin	Locker	Lunch	Court-yard	Main	Circu-lation	Xerox	Ele-vators
Courtroom	--	110	116	107	88	71	104	104	135
Bulletin Board	112	--	15	22	40	100	115	85	120
Locker Room	118	16	--	15	38	102	110	60	118
Lunch Room	106	21	16	--	22	85	91	60	93
Courtyard	89	43	37	24	--	64	75	44	80
Main Entrance	73	101	104	88	62	--	35	44	63
Circulation	106	114	112	90	79	33	--	30	30
Xerox Machines	108	88	77	64	45	45	30	--	38
Elevators	130	116	114	92	79	65	30	40	--

Euclidean

	Court-room	Bulle-tin	Locker	Lunch	Court-yard	Main	Circu-lation	Xerox	Ele-vators
Courtroom	--	175	163	159	213	110	155	175	190
Bulletin Board	179	--	65	53	94	180	225	250	265
Locker Room	162	62	--	23	58	192	211	234	246
Lunch Room	156	52	21	--	15	163	208	222	250
Courtyard	201	91	55	15	--	105	152	178	191
Main Entrance	109	178	193	160	109	--	65	83	101
Circulation	160	228	214	206	155	62	--	32	46
Xerox Machines	179	248	231	218	175	80	34	--	56
Elevators	194	201	245	238	192	100	49	54	--

Route

	Court-room	Bulle-tin	Locker	Lunch	Court-yard	Main	Circu-lation	Xerox	Ele-vators
Courtroom	--	112	115	105	80	73	105	105	135
Bulletin Board	113	--	20	24	40	103	119	83	120
Locker Room	118	17	--	19	40	100	111	82	112
Lunch Room	107	22	17	--	20	83	90	64	96
Courtyard	88	41	39	22	--	60	75	43	70
Main Entrance	72	102	102	85	63	--	34	41	69
Circulation	105	116	110	91	77	36	--	30	30
Xerox Machines	105	85	80	61	44	44	33	--	41
Elevators	132	118	110	74	80	63	30	39	--

Second Euclidean

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